Building a Bridge to the Corn Ethanol Industry

High Plains Corporation's Portales, NM Facility

For the National Renewable Energy Laboratory
And the U.S. Department of Energy, Office of Fuels Development
Subcontract ZXE-9-1808-06

FINAL REPORT

Submitted by
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Executive Summary

SWAN Biomass Company, High Plains Corporation and Weatherly, Inc. were awarded a contract by NREL to evaluate the opportunity for converting all or part of the High Plains Portales, NM ethanol facility to biomass feed. The Portales plant, owned by High Plains, currently produces about 10 million gallons per year of ethanol from milo feed.

SWAN Biomass conversion technology is the basis for the new process design. SWAN first evaluated possible biomass feedstocks available close to the existing facility. Cotton gin trash was found to be abundant in the area, available for the cost of hauling, and suitable as a feedstock for the manufacture of ethanol. SWAN then optimized the design of the biomass plant, and performed extensive economic evaluations tailored to the specifics of the feedstock, facility site and owner. Weatherly, Inc., a process engineering company with expertise in the design and construction of ethanol plants, reviewed the existing equipment at Portales, and estimated the costs for modifying that equipment to allow the plant to run on biomass. High Plains supported both efforts, and investigated means for implementing the new technology.

The proposed modifications would cost \$30 million. Most of the capital cost would be for biomass pretreatment equipment and the large fermentation vessels needed to convert biomass in high yield. The modified facility would produce 11.3 million gallons per year of ethanol from 725 tons/day of cotton gin waste. The Base Case projected discounted rate of return is 23.5%, and the NPV_{12} is \$18 million. Sensitivity analysis shows that increases in cellulase enzyme or feedstock costs above the Base Case assumptions would significantly cut into the profits, but the modifications would still be justified financially. The Base Case assumes that the unreacted solids can be sold as an animal feed component, but even if the solid product is sold as a solid fuel, the estimated project rate of return is still attractive. The rate of return on invested capital would increase significantly if part of the capital were borrowed for construction at today's interest rates.

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Introduction

The National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy (DOE) Office of Fuels Development (OFD) have cost-shared several studies to examine introduction of biomass feedstocks into existing grain-to-ethanol processing plants. Processes utilizing biomass as a feedstock for ethanol production require higher initial capital costs than those that process conventional starch feedstocks. The conversion of existing starch-based facilities promises to reduce those capital costs and may speed initial commercialization of biomass-to-ethanol technology.

SWAN Biomass Company and its collaborators, High Plains Corporation and Weatherly, Inc., have completed one of these NREL-cost-shared studies, the conversion of High Plains' Portales, New Mexico milo-to-ethanol facility to use locally available lignocellulosic biomass as feedstock. SWAN Biomass Company has rights to suitable technology for biomass conversion to ethanol. In part, this technology was developed in cooperation with NREL. High Plains Corporation owns three ethanol production facilities, including the one in Portales, NM. The Portales plant is relatively small, and has not been able to consistently make a profit. It was therefore targeted as a candidate for possible conversion to a lower-cost feedstock. Weatherly, Inc. is an Atlanta, GA engineering firm that is owned by Chematur, a Swedish engineering company that builds ethanol plants throughout the world. The three companies interacted closely to produce a very promising design for possible implementation at Portales.

This Final Report provides the results for each of the first five work elements contained in the Statement of Work for the project (Appendix A), and then summarizes the conclusions and recommendations of the participants.

Work Element 1: Feedstock Selection

SWAN hired Mike Davis, a biomass expert based in the Imperial Valley of southern California, to conduct the first phase of the feedstock selection study. Mr. Davis visited the Portales plant, and surveyed possible biomass feedstocks in eastern New Mexico and western Texas in late April 1999.

Davis' objective was to evaluate the availability, cost and feasibility of harvesting substantial and reliable sources of feedstock material in the Portales, NM area. To accomplish this objective, he conducted both telephone and in person interviews with processors, harvesting companies, farmers, truckers, feed brokers, government employees and academia in western Texas and eastern New Mexico. He identified over 17,000,000 annual tons of agricultural wastes as candidate feedstocks, including cotton gin trash, sorghum stover, wheat straw, corn stover, corn silage and peanut hulls. Davis' report is attached as Appendix B.

Cotton Gin Trash

By far the lowest cost material identified by the feedstock survey was cotton gin trash (CGT). Cotton is a major crop in the southwestern United States. The USDA maintains major cotton processing research facilities in the vicinity of Portales. Their Cotton Production and Processing Research Unit is in Lubbock, TX, and their Southwestern Cotton Ginning Research Laboratory is in Mesilla Park, NM. A bale of cotton usually generates about 700 pounds of CGT when it is cleaned. The eight eastern counties of New Mexico surveyed produce about 54,000 bales of cotton per year, and about 3,000,000 annual bales are produced in nearby Texas.

A small amount of CGT is pelletized and marketed as cattle feed, but most of it is a disposal problem for the processor. The estimated supply of such trash in the Portales area is slightly more than 1 million tons per year, and it is available at zero cost to anyone who will haul it away. The gin operators contacted in the study indicated they would be interested in long-term contracted outlets for their material at no cost. Davis estimated the transportation cost for this material to average $11.57/ton (between $5 and $18 per ton, depending on location).

Other Feedstocks

In contrast, the costs for the other potential feedstocks identified by Davis were significantly higher, generally about $40/ton at the plant gate. Peanut hulls are a bit lower in price, averaging about $30/ton. The price for corn silage and peanut shells is determined by their value as cattle fodder, about $20/ton (to which haulage costs must be added). Wheat straw, corn stover and sorghum stover are not usually harvested in this area. The high estimated price for these materials results from high baling costs (1800 lb. square bales) of $25/ton for the stovers and $35 to $40/ton for the wheat straw. These prices include both the farmer's costs and a collection incentive.

These estimated costs are somewhat higher than baling costs reported or estimated for other projects. The corn stover collection project reported[1] baling costs of $14.60/dry ton (paid to an independent baling contractor), in addition to a payment to the farmer of $2.90 to $15/dry ton. Average cost per dry ton delivered was $31.60 to $35.70, the latter applying to costs when only half the stover in any field was harvested. Leaving part of the stover in the field allowed collection of a cleaner product, that is, biomass containing less of dirt and rocks. Merrick & Company[2] reported that the cost of corn stover at High Plains' York, Nebraska facility would be about $35/dry ton, based on proprietary information available to High Plains. This cost was derived assuming that only 60% of the stover would be collected in any given field. The Gridley rice straw project[3] estimated the cost for baling rice straw at between $17 and $25/dry ton in California, with hauling costs between $8 and $12 per dry ton. The lower hauling costs at Gridley reflect shorter hauling distances. At Gridley, no cash incentives for the farmer were included; the incentive for the farmers to provide rice straw was not added profit, but avoided problems with straw disposal.

Cotton Gin Trash Composition

Table 1 in the Davis feedstock report (Appendix B) presents literature values for CGT analysis, but these data are not in sufficient detail to allow estimation of ethanol process yields. The table shows that crude fiber content for various samples of CGT from the southwest is between 42.1% and 21.8% on a dry basis, with an average of 32.5%. This level is high enough to suggest cotton gin trash might be an attractive feedstock.

Axion Analytical Laboratory, Chicago, Illinois, analyzed a sample of CGT collected by Mike Davis. A second aliquot from the same sample was tested for total available sugars and lignin only, with nearly identical results to the first aliquot.* The total available sugar content was 38.1% and 36.0% of the dry biomass in the two samples run. These numbers translate into 32.1% and 34.0% fiber (cellulose and hemicellulose), in good agreement with the average crude fiber measurements discussed above.

The sum of all the components on a dry basis is slightly less than 91%, as shown in Table 1. The engineering studies, and economics developed from them, utilize the actual measured values of sugar content, but sensitivities were also run assuming the "missing" mass to be fermentable sugars. It is unlikely that sugar contents will actually be this high, but using such values for sugars provides an upper limit estimate of the sugar content of the feed. The data from the Davis report show that some variation should be expected in fermentable content, but it is not known if the differences observed in that report are due to analytical technique, sample type, sample place of origin or crop variables such as weather or cotton variety.

Table 1
Cotton Gin Trash Composition

Component	**Amount (% Dry)**
Fiber	34.03
Lignin	38.32
Protein	7.19
Fat	0.85
Sol. Ash	4.41
Insol. Ash	4.38
Acetate	1.76
Total	**90.94**

The acetate content of the feedstock is high enough to require acetic acid removal from the fermentation broth so that the yeast can ferment xylose at a reasonable rate. Acetic acid will become a minor byproduct from operation of an ethanol facility that uses CGT as a feedstock.

The protein content of the CGT is 7.19%, calculated by multiplying the measured nitrogen concentration by 6.25, the procedure indicated in the Davis feedstock report. The protein level is high enough that the solids generated as a co-product of ethanol manufacture should have use as a component in cattle feed.

* See Appendix C for more complete sample analysis

Proper processing will not harm the initial protein, and the removal of carbohydrate and the generation of yeast bodies that will occur in the process will significantly increase the protein concentration in the solid product.

Work Element 2: Site Assessment

A site visit took place on April 28 - 29, 1999. During this visit, the High Plains plant manager, Steve van Norden, conducted a plant tour. Weatherly personnel found the documented information available to them at the Portales facility to be well organized and up-to-date, and the Portales staff well informed and very cooperative.

The Portales ethanol plant currently produces about 10 million gallons per year of fuel ethanol, using milo as the feedstock. The facility was designed to produce dried distillers grain and solubles (DDGS) and liquefied carbon dioxide as byproducts. The plant sits on 15 acres of land in an industrial park, and is contained in three steel buildings. Table 2 (attached) lists the existing equipment in the Portales facility, and a plot plan is included in Appendix D. The main building houses the office, control room, cook area, fermentation area, solids separation area and drying area. The distillation, adsorption, and evaporation sections are located outside, just north of the main building. The boiler building houses two boilers capable of 40,000 lb/hr of steam each, three air compressors, and a water softener. The feed storage building can hold approximately 1000 tons of dried distillers grain and solubles (DDGS). Next to the boiler building is the alcohol storage area capable of holding 1,000,000 gallons of product.

Feed Handling

Milo, the primary feedstock, is delivered to the plant in grain trucks. The trucks are bottom unloaded into a receiving hopper. The grain then is passed through a scalper to remove any debris and fines and is transferred to the whole grain storage bins.

Conveyors and elevators transfer the milo to the hammer mill feed hopper, from which it flows to the hammer mill where it is ground. The milled grain is fed to the milled grain storage bin. Dust from the milling and conveying operation is recovered by a dust collection system and is also sent to the milled grain storage bin. A feed screw conveyor continuously feeds the grain from the milled grain storage bin to the liquefaction section of the plant.

Liquefaction and Cooking

In the liquefaction section, the grain is fed to a mix vessel, where it is mixed with neutralized hot water. Alpha-amylase enzyme is added to the mix vessel as well. The mixture is agitated to promote good wetting of the meal. Overflow from the mix vessel goes to the primary liquefaction vessel. The primary liquefaction vessel is a three-stage agitated vessel. The solution is controlled at a pH of 5.5-6.5 primarily by adjusting the pH of the neutralized water, with additional trim control by caustic when necessary.

The resulting mash is pumped through a hydroheater where it is mixed with steam and sent to the cooking vessel. The mash is then flash cooled in a nine-stage agitated secondary liquefaction vessel. Flash vapor form the secondary liquefaction vessel is condensed in flash condensers and sent back to the mix vessel. A controlled pH of 4.0-5.0 is maintained by recycling thin stillage from the evaporator feed tank and by the addition of acid as needed. The mash is also mixed with recovered water from the distillation section and is cooled in the beer still economizer and the prefermentation cooler. The cooled mash is sent to the fermenters. Gluco-amylase enzyme is added to promote the conversion of starch polymers to sugar.

Fermentation

The fermentation section is a batch operation, designed so that the liquefaction, distillation, and drying sections can be operated continuously. The plant contains five fermenters and a beer well, each with a working volume of 165,000 gallons (186,121 gallons total volume). Total cycle time for fermentation is 60 hours.

Yeast is grown from a small quantity of starting inoculum in a pair of yeast propagation reactors. A portion of the liquefied mash is sent to the yeast reactors as growth medium. Measured quantities of yeast, urea, and penicillin are added. During the fill, air is sparged into the reactor to promote aerobic yeast growth. To maintain the slurry at the required temperatures, excess heat of reaction is removed by circulating a portion of the slurry through the yeast reactor coolers. Agitation is provided to ensure good dispersion of the air into the slurry. Each yeast reactor operates on a 24-hour cycle to allow for yeast propagation, yeast transfer to the large ethanol generating fermenters, and yeast reactor cleaning. Each yeast reactor provides the quantity of active yeast that is needed by a fermenter at the beginning of the filling operation.

During fermentation, the yeast consumes glucose to produce ethanol and carbon dioxide. The reaction is exothermic. The heat of reaction is removed by circulating a portion of the mash through the fermenter cooler. The temperature of the fermenter is kept at approximately 90°F. The mash is stirred by the fermenter agitators.

The carbon dioxide from the fermenters is currently removed, scrubbed, and discarded. The original design included the recovery and liquefaction of the CO_2, but the facility no longer produces liquefied carbon dioxide. High Plains installed a new carbon dioxide blower in order to operate the carbon dioxide scrubber to recover ethanol that would be lost otherwise. The remaining carbon dioxide recovery and liquefaction equipment has been removed from the plant.

When the fermentation is complete, the batch is pumped to the beer well. The beer well is the same size as the fermenters. The beer well effluent is heated with liquefied mash in the beer still economizer and further heated with beer still bottoms in the beer still preheater before being sent to the beer still.

Distillation

In the beer still, ethanol is separated from most of the associated water by distillation. The wet ethanol is dried in the adsorption section.

The distillate vapor from the beer still is compressed by the ethanol blower and fed to the adsorption system. The adsorption system consists of three molecular sieves that operate automatically.

During the adsorption step, the ethanol-water vapor flows up a pressurized fixed bed of molecular sieve. Water is absorbed and anhydrous ethanol vapor leaves the top of the adsorbers. The anhydrous ethanol from the adsorbers is condensed in the anhydrous ethanol condenser. The ethanol is then pumped by the ethanol product pumps through the product cooler to the ethanol surge tanks.

During the regeneration step, water is removed from the sieve first by depressurizing and then by purging with a portion of anhydrous ethanol vapor. The regeneration is downflow and is done under vacuum. Purge ethanol-water vapor removed from the sieve is condensed in the regeneration gas condenser. The condensed liquid is recycled to the beer still to recover the ethanol. Vacuum for regeneration is maintained by the regeneration vacuum pumps. When the regeneration is complete, the adsorber is repressurized to adsorption pressure using a portion of the anhydrous ethanol vapor.

All liquid leaving the top section of the beer still is fed to the water concentration column. Steam is sparged into the bottom of the column to strip out the ethanol. Concentrated ethanol vapors from the top of the column are sent back to the beer still. The water concentration column bottoms is sent to the fermenters.

The whole stillage from the bottom of the beer still is cooled by exchange with the beer still feed in the beer still preheater and sent to the centrifuge feed tank. The stillage is then pumped to the centrifuge. The centrifuge removes the fibrous and insoluble material from the stillage. Most of the centrate (thin stillage) is collected in the centrate vessel and is transferred to the evaporator feed tank. Some of the thin stillage is used as scrubbing liquid in the DDGS gas scrubber and some is recycled to the fermenters.

Evaporation

In the evaporation system, heat for the first stage concentration is supplied by condensing the beer still reflux in the evaporator and beer still reflux condenser, and by condensing ethanol vapor product from the adsorption system in the evaporator and anhydrous ethanol condenser. This heat concentrates the stillage and the low-pressure steam generated from these two evaporators is fed to the first stage vapor compressor. The condensed reflux from the evaporator and beer still reflux condenser flows into the beer still reflux drum and is pumped back to the beer still. The condensed ethanol from the evaporator and anhydrous ethanol condenser flows into the anhydrous ethanol drum and is pumped to the ethanol surge tanks.

The partially concentrated syrup is fed through the feed/condensate exchanger to a vapor compression evaporator to complete the syrup concentration to 50% solids. The concentrated syrup is pumped to the syrup tank. Steam from the vapor compression evaporator and first stage vapor compressor feeds the second stage vapor compressor. Compressed steam from the second stage vapor compressor supplies heat to the vapor compression evaporator and the distillation system. The condensate from the vapor compression evaporator shell side flows into the evaporator condensate drum. This condensate is pumped to the feed/condensate exchanger. Part of the condensate is used to desuperheat the compressed steam from the second stage vapor compressor. The remainder is sent to the liquefaction section.

The vent stream from the evaporator and beer still condenser shell side is condensed in the beer still vent condenser. The condensate flows into the beer still reflux drum. The vent stream from the evaporator and anhydrous ethanol condenser shell side is condensed in the anhydrous ethanol vent condenser. The condensate flows into the anhydrous ethanol drum.

A vacuum system is used to quickly develop design suction conditions for start-up of the first stage vapor compressor and the second stage vapor compressor.

Solid Byproduct Handling

The plant is designed to produce a high protein by-product, distiller dried grain and solubles (DDGS). The DDGS contains less than 10% moisture, which leaves the protein in a stable condition.

The cake from the centrifuge is mixed with syrup from the evaporation system. This mixture is blended with recycle DDGS in the dryer feed blender to give a combined solids content of about 70%. The resulting mixture is conveyed to the steam tube dryer. Steam in the tubes provides the evaporation heat to dry the solids. Air passes through the dryer to remove moisture as it evaporates from the solids. A portion of the DDGS leaving the dryer is recycled to the blender. The steam condensate from the dryer is sent to the hot condensate drum.

The dryer product is pelletized in the DDGS pellet mill, cooled in the pellet cooler, screened by the pellet screen and sent to the DDGS storage bins.

Portales reported that they recently have had problems selling their DDGS. Normally, the protein level in the milo DDGS is quite high compared to corn-based DDGS, about 36% as sold (41% on a dry basis). However, with the economic problems in Asia in 1999, the soybean farmers have been exporting less of their crop (normally shipped through Houston), making this material available as a superior domestic animal feed. Portales prefers to sell their DDGS to dairy farmers, rather than to feed lots, because dairies contract for feed one year in advance and take delivery on a regular basis. Feedlot sales are either short-term contract or spot market, and fluctuate widely. Recently, dairies have opted for the higher-grade soy product. High Plains would definitely view any conversion process that avoided the need to sell an animal feed coproduct at a high price as a positive feature.

Utilities

City water is available at the battery limits. A portion of the water is used as cooling water make-up. The remainder of the water is softened in the water softener and stored in the softened water tank. The softened water is sent to the deaerator. The deaerator capacity is 42,100 lb/h.

Recovered water from the distillation section and condensate from the evaporation section are major sources of process water. Because the water from these sources is acidic, it is neutralized with caustic in the process water tank before being fed to the liquefaction system.

Two natural gas fired boilers supply the steam requirements in the plant. Originally, one of the boilers was coal burning, but has been retrofit to burn natural gas. The boilers are rated for 150 psig although the plant typically runs at a steam pressure of approximately 135 psig. Most of the steam is used for DDGS drying. The remainder of the steam is used in the liquefaction and distillation sections.

Condensate from the steam tube dryer is returned to the deaerator.

The cooling tower cools the circulated water to 75°F. The cooling water treatment package provides chemical treatment for the cooling water system. There are two cooling water pumps each with a capacity of 3500 gpm. The original cooling tower has a capacity of 2850 gpm. Another cooling tower has been added which has a capacity of 3800 gpm. This cooling tower utilizes the chilled water pumps to pump the cooling water.

The plant originally included a chiller package, which was used in the liquefaction section and the CO_2 recovery/liquefaction section. The CO_2 recovery/liquefaction section is no longer in service and the cooling water temperatures are low enough year-round for the operation of the liquefaction section. Therefore, the chiller package is no longer necessary and is not in service.

There is no wastewater treatment facility on site. The plant is connected to the city sewer system, and was originally allowed to send 300,000 ppm BOD to the city. They currently send 20,000 to 30,000 gallons per day of water to the sewer containing about 4000 ppm BOD. The city has indicated that they can accept almost any reasonable volume of water, but any higher BOD than 4000 ppm will incur a charge of $1/1000 gallons, and there is no guarantee that they can continue to accept the increase. Any BOD above 5000 ppm will likely lead to rejection.

The electric switching equipment is oversize for current operations, and should have the capacity to handle any additional equipment needed.

Considerations

Conversion of the Portales facility to utilize biomass feedstock offers an opportunity for improved profit for High Plains primarily because biomass feedstock will be cheaper than milo, the current feedstock. But a number of other features of the SWAN process offer improvements that High Plains finds attractive. The installation of continuous-flow fermenters is likely to reduce the number of operators required by one per shift. Eliminating the evaporation and solids drying areas could also reduce operating costs and maintenance problem areas. If the solid residue is burned, significant fuel (natural gas) and electric power costs could be avoided. Any or all of these features would improve the bottom line for the plant owners.

Work Element 3: Needed Modifications to Existing Equipment

The two most significant changes needed to convert Portales from milo feed to biomass feed are installation of SWAN's pretreatment process and of much larger fermentation (actually, simultaneous saccharification and fermentation, or SSF) vessels. Determination of the needed modifications was an iterative process. Initial effort on work element 3 centered on defining modifications that might be needed to support these unit operations, including feed handling, distillation, solid-liquid separation, and utilities. Weatherly considered ethanol production rates of both 10 million gallons per year and 20 million gallons per year. SWAN then developed a tentative Base Case using Weatherly's information (under work element 4), and provided Weatherly with estimated energy and material balances. Weatherly then used these balances to derive the design and costs for the modifications needed convert Portales to biomass feedstock.

General

The first step in the evaluation of needed modifications to the plant was to determine the maximum throughput of the existing equipment. The current limiting factor for ethanol production is the evaporation equipment. Relieving this bottleneck would allow the plant to produce 17 million gallons of ethanol per year. The next limitation would be in the capacity of the molecular sieves that break the ethanol-water azeotrope. However, when the facility is converted to biomass feedstock, the beer fed to the distillation section will be lower in ethanol content and higher in water than is experienced when grain is used as a feedstock. Therefore when biomass is processed, the limiting factor in plant rate becomes the distillation section. With the new still feed conditions, the unmodified distillation column will flood at plant rates greater than approximately 12 MMGPY. The plant rate that was the most cost effective was determined to be 11.3 MMGPY. It is on this production basis that the modifications were designed and costed.

Feed Handling

Use of CGT as a feedstock results in a lower yield (gal EtOH/ton dry feed) than when milo is the feedstock. Therefore, the feed handling section will have a higher throughput, even though the ethanol production rate is about the same as before modification. It is assumed that the CGT will be delivered as a pelletized material; the gin owners currently pelletize some of the CGT for sale as animal feed. The following conveyors in the feed handling section are too small and will have to be replaced in the Base Case scenario:

MH101	Grain Unloading Conveyor
MH102 A&B	Grain Scalpers
MH103	Whole Grain Leg

MH104 A&B	Silo Conveyors
MH105	Hammer Mill Feed Elevator
MH106	Hammer Mill Rotary Feeder

Fermentation

The biomass fermentation system will require much larger tanks than are required for grains because the required residence time is significantly longer, and because the sugar concentration in the feed is lower. There appears to be room on the High Plains property to build three or more large fermentation tanks, as well as whatever other facilities are required.

The plant currently has 5 fermenters and a beer well, which have an operating volume of 165,000 gallons each. The current fermenters and beer well (6 tanks in total) will be piped so that they can function as the beer well for the new process. The current fermenter coolers are too small to reuse with the new fermenter tanks and are not required as part of the beer well. The current fermenter pumps also are too small. The current fermenter pumps will be replaced with 3 new beer well pumps. Piping changes will be made as required between the beer well tanks and the beer well pumps.

Three new fermenter (SSF) tanks of 750,000 gallons each will be added to the plant. Each of the fermenter tanks will include a new fermenter cooler and a new fermenter pump.

Distillation

The current beer still (V-109) consists of two sections. The beer is fed to tray 24. The liquid from the top section of the column (top section = trays 25 - 40) is extracted from the column at tray 25 and fed to the water concentration column (V-110). Vapors from the water concentration column are fed above tray 24 in the beer still.

The lower ethanol content in the beer feed to the beer still when CGT is used as a feedstock means that more trays will be required for the distillation. Tray 25 will be modified such that the liquid from tray 25 flows to tray 24 instead of V-110. The liquid from the bottom of the beer still will be fed to the top of the water concentration column (V-110). This configuration will require the addition of new pumps. The vapor from the water concentration column will be fed to the bottom of the beer still (below tray 1). A new 5-tray column will be added that will serve the same purpose as the bottom section of the current beer still. The beer feed from the fermentation section will be fed to the top of this new column. The vapor from this column will be fed to the bottom of the beer still. The steam that is currently fed to the bottom of the beer still will now be fed to the bottom of the new column. The hot stillage pumps (P-117A&B) will be used to pump the bottoms from this new column to the centrifuge feed tank.

The evaporation system will no longer be utilized in its current configuration. There is no need to evaporate the thin stillage to make syrup; SWAN experience shows that there will be no significant protein soluble in the stillage.

The evaporator and beer still reflux condenser (E-113) will still be used as the beer still reflux condenser but will use cooling water instead of thin stillage to accomplish the condensing. Similarly, the evaporator and anhydrous ethanol condenser (E-114) will still be used to condense the ethanol vapor from the molecular sieves but will also utilize cooling water instead of stillage.

Currently the steam being fed to the bottoms of the beer still (V-109) and the water concentration column (V-110) comes from the evaporation system. The plant will be modified to use steam from the low-pressure steam header. The steam will be let down in pressure to match the current operation.

The operation of the evaporation system will be simplified considerably. The vapor compression evaporator (E-115) and vapor compressors (C-105 and C-106) will not be required.

The beer still preheater (E-109) is now too small and will be replaced with a larger exchanger.

Drying

The existing centrifuge is not large enough to accommodate the increase in solids in the beer still bottoms that will be created when CGT is used as a feedstock. A new centrifuge will be added.

Although the solid waste can be sold as animal feed, it will be sold wet so that the steam dryer will no longer be utilized.

Utilities

The SWAN process requires high-pressure steam that is currently unavailable at the plant. A new boiler capable of delivering 400 psig steam will be added to the facility. New boiler feedwater pumps will be included as well as piping to the pretreatment area.

Cooling water requirements will increase in the new plant configuration. A new cooling water tower and pumps will be provided.

A new packaged chiller will be provided for the pretreatment area. It may be possible to use equipment from the original chiller plant, thus reducing estimated capital costs.

Waste Water Treatment

The plant currently has no wastewater treatment facility. The wastewater from the plant is fed directly to the city sewer. The addition of the biomass process will increase wastewater volume from the plant, although it is not clear whether the total BOD content of the wastewater also increases. An anaerobic digester will be added to the plant to lower the water BOD content before it is sent to the city sewer. This addition seems prudent, given the tight limits allowed by the city of Portales on the wastewater quality. It may be possible to eliminate this operation, but additional data are needed on the wastewater quality before doing so.

Work Element 4: Design and Costing of New Facilities

SWAN Biomass Company created a spreadsheet computer program to optimize the design for conversion of biomass to ethanol at Portales. The spreadsheet evaluates a particular design, and calculates a capital charge-based cost in dollars per gallon for the ethanol that design will produce. This cost assumes a 15% discounted rate of return on the initial capital investment in the new equipment needed. The output of the spreadsheet includes all stream compositions, flows, temperatures and pressures, as well as a list of capital cost for each unit operation, and detailed operating costs and utility requirements.

This process spreadsheet is linked to a second spreadsheet that uses the design parameters for the process and a set of economic assumptions that reflect the business perspective of High Plains to calculate a complete financial *pro forma* for the commercial facility. Two important results on this financial spreadsheet are the expected rate of return for investments in the facility, and the net present value (NPV) at a specified discount rate. For the purposes of this work element only, the discount rate was specified to be 15%, matching the rate of return used to calculate the capital-charge-based ethanol cost, so the spreadsheet reports a NPV_{15}. A more appropriate discount rate for the ethanol industry (12%) is used in work element 5.

The first step in the procedure to determine the Base Case process design was to specify a series of designs, primarily varying solids feed rate, cellulase enzyme dosage, and SSF residence time to determine which set of parameters give a design with the best economic performance. Feed composition, pretreatment conversions, enzyme cost and ethanol concentration sent to the still were kept constant in the initial evaluations. The feed was assumed to be CGT, as analyzed by Axion Analytical. Pretreatment conversions were consistent with SWAN experience. Enzyme was assumed to be available for purchase at $0.50/liter, and not to be manufactured on site. The ethanol concentration in the distillation feed stream was fixed at 70 g/liter, provided that no more than 50% of the SSF product liquid was recycled to achieve this concentration.

The resulting tentative Base Case design handled 725 tons/day of CGT feedstock, and produced 9.66 million gallons of ethanol per year. It used an enzyme dose of 5 IFPU/g cellulose and a residence time of 72 hours, with three SSF tanks in series. The cost of ethanol was estimated to be $0.80/gallon, and the capital investment required was $29 million. Longer residence times or higher enzyme doses would produce more ethanol, but the cost of producing that ethanol rose faster than the income generated by it.

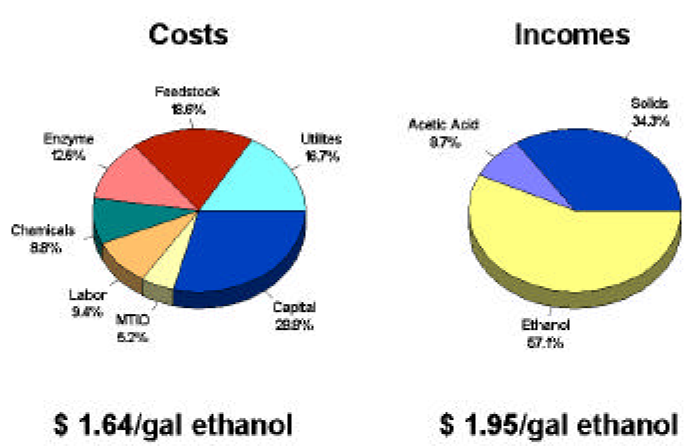
The next step was to transmit the resulting design to Weatherly, who provided more accurate capital costs for the additional equipment needed to convert the Portales facility. Weatherly also checked the prices for chemicals and utilities at Portales. The revised capital and operating costs were then used to repeat the optimization exercise, and come up with the final Base Case design.

The final Base Case is similar, but not identical, to the preliminary Base Case. The solids feed rate is still 725 dry tons per day of CGT, but the enzyme dose is increased to 10 IFPU/g. cellulose, and the ethanol production rate is increased to 11.28 million gallons per year. The cost of the ethanol is $0.80 per gallon, and the initial capital required is $30 million.

The product solids are assumed to be sold as a component of animal feed based on their protein content. Protein is valued at $0.20/lb, equivalent to protein in corn fiber when corn is selling for $2.50/bushel, a long-term average price. Acetic acid is valued at $0.17/lb, which is low, but thought reasonable for Portales. Methane generated in the anaerobic digestion section of the plant is burned in the boilers, and is not available for sale. Carbon dioxide is assumed to be discarded, as it is now at Portales. Portales used to sell CO_2, but stopped and removed the equipment in 1999.

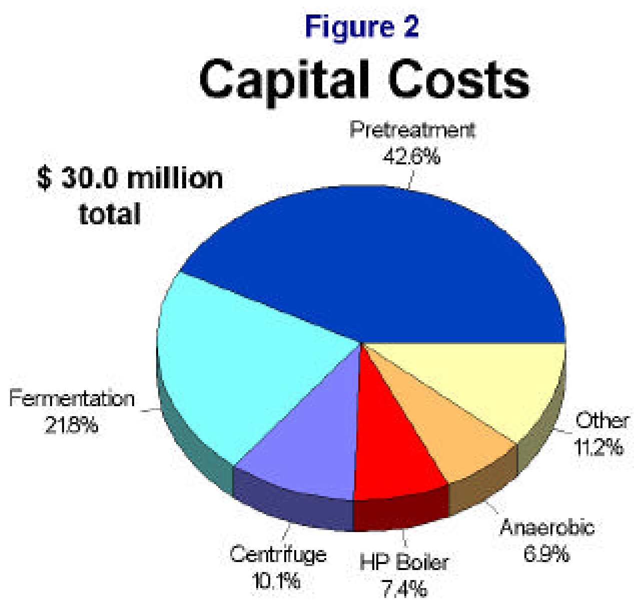
Figure 1

Capital Charge Economics
Portales Base Case



Among the variable costs, the most significant are those for feedstock and enzyme. Sensitivity of the results to increases in these costs are examined below. Labor costs assume lower manpower than the plant currently requires, based on the discussions with plant management. Changing from batch to continuous fermentation and the elimination of both evaporation and drying will help reduce manpower needs.

Figure 1 shows ethanol costs and incomes for the modified Portales facility broken down into major categories. An ethanol value $1.10 per gallon is used, as specified by High Plains. Capital is clearly the largest cost (capital charge basis, using a 15% rate of return), and feedstock, utilities and enzyme costs are also large. Labor, chemicals and MTIO are less important to the overall costs. Solids sales for protein value make up about 1/3 of the total income expected; acetic acid provides less than 10% of the projected income.



Capital costs are presented in Figure 2 below. The construction total is $19 million, and engineering, contingency and royalties bring the grand total cost up to $30 million. The contingency is quite large (20%, or $5 million), and could be reduced once more data on processing CGT is accumulated. There is no High Plains home office cost assigned to these project costs. Figure 2 below shows that pretreater and fermentation tank costs make up well over half of the total construction capital, and that the pretreater is twice the cost of the fermenters. The new centrifuge, high-pressure boiler and anaerobic digestion tank are also significant cost items.

There is a good chance to modestly reduce capital costs through the purchase of second-hand equipment. The water column needed in the distillation area, the new cooling tower, and the high-pressure boiler are likely to be available second hand; suitable pieces of equipment were located by Weatherly available in April 2000. If similar equipment can be located when a project is launched, the total saved on installed capital cost is about $650,000, which would reduce the Base Case ethanol cost about $0.015 per gallon, and the total required capital about $1 million.

SWAN investigated the use of second hand equipment in the pretreatment section as well. It appears likely that multiple trains of smaller pretreatment equipment could be used in place of the new equipment specified in the Base Case, without increasing costs. Although there seems to be no cost advantage to making such a substitution, there are a number of reasons to prefer the smaller equipment, including reducing the scale-up from experimental experience, providing redundancy in the pretreatment area, and significantly reducing construction time (since the pretreatment equipment is the longest delivery time item needed).

Sensitivity of the capital charge case economics to some of the process assumptions was tested. At Base Case (low) enzyme cost, reducing enzyme use produces a roughly comparable reduction in revenue from ethanol, and the cost per gallon of ethanol produced is relatively flat. However, if enzyme costs are higher, $1/liter instead of $0.50/liter, use of a lower enzyme dose becomes much more attractive despite reduced revenue from lower ethanol production.

Sensitivity to feedstock composition was also tested. If the cellulose content of the CGT is determined by difference (29.56 %), instead of by using the measured value (21.22 %), ethanol yield increases by 2.7 million gallons, and the cost of the ethanol drops a nickel per gallon. This is an optimistic case, which assumes that all of the "missing" material not identified in the feedstock analysis turns out to be cellulose. This amount of cellulose was considered to be the maximum fermentable sugars possible in this feedstock.

The sensitivity to increases in capital cost was found to be symmetrical around the Base Case data point. Adding $5 million to the capital cost will raise the ethanol cost by thirteen cents per gallon, and subtracting the same amount from the capital cost will lower the ethanol cost an equal amount. This amount of capital cost reduction may be possible if second-hand equipment can be located and purchased, and with more accurate engineering that should be possible after hard test data on the proposed feedstock are available.

Several cases were also tested using corn stover as the feedstock. If this feedstock were used, capital cost could be reduced to $20 million because the stover is richer in fermentable carbohydrates than is CGT, and the pretreatment and fermentation sections would be significantly smaller than in the Base Case. However, the cost of the feedstock would be higher, and the solids, because of their lower protein content, would have to be burned or sold as boiler fuel. The capital charge case cost of ethanol from corn stover would therefore rise to about $1.78 per gallon, far too costly to be of interest in today's ethanol market.

Work Element 5: Financial Analysis and Sensitivities

The square case economics for the use of CGT to produce ethanol were very promising, but not definitive for the envisioned commercial implementation of SWAN's biomass-to-ethanol technology. Work element 5 was the generation, utilizing the process configuration derived in Work Element 4, of a *pro forma* financial analysis for the project, and the examination of the sensitivity of that analysis to changes in various parameters.

During the course of this study discussions were held between High Plains and a third party regarding the possible purchase of the Portales facility by that third party. As is shown below, the availability of the Small Producer Tax Credit (SPTC) to the third party (and not to High Plains) makes ownership of the facility by the third party more profitable to that third party than it is to High Plains. The ownership of the facility by an entity that could capture the benefits of the SPTC therefore became the Base Case for this Work Element, with the continued ownership by High Plains treated as a sensitivity.

The financial analysis shows that the proposed modifications would offer excellent rates of return on invested capital. For 100% equity financing, the DCF-ROI would be 23.5% on the initial investment, and the NPV_{12} would be $18 million.

This Base Case financial analysis assumes the capture of a small producer tax credit (SPTC) that would likely be available for a purchaser of the facility, and continuation of blending and sales tax credits at a reduced level (from the state) after the expiration of the current Federal tax subsidy in 2007. High Plains Ethanol's production is too large to qualify for the small producer tax credit, however.

For all *pro forma* evaluations inflation is projected at 3.5% annually, and a tax rate of 38% is used. Sustaining investment is made annually at a level of 1% of the initial capital for years 2 though 13 of the 15-year project life. Depreciation is calculated on a 10-year double declining balance/straight-line (DDB/SL) basis. For all of the cases presented it is assumed that no initial investment in working capital is made because the converted facility is expected to absorb the working capital of the pre-existing one. This last assumption is very conservative, because the feedstock cost for the converted facility will be an order of magnitude less than for the facility operating on grain.

Construction in each case takes one year, and, although not reflected in the economics presented, the facility will continue to operate on grain for most of the time during the construction period. Personnel currently operating the facility will be trained for operation of the converted facility. Startup costs are set at 4% of the initial fixed capital. Seventy five percent of the nameplate capacity is expected during the first full year of operation.

Table 3

Financial Sensitivities
From Portales Base Case

Variable	Change in Variable	Change In ROI,%
Feedstock cost	+ $5/ton	-3
Byproduct solids value	-10%	-2
No tax credit after 2007	-$0.54/gal EtOH	-2
No SPTC	-$0.10/gal EtOH	-4
Debt/Equity, cost of debt	50/50, 10%	+12
	50/50, 15%	+10
	70/30, 10%	+14

Ethanol product in each evaluation is sold at $1.10 per gallon, plant gate, in year 2000 dollars, as it is from the unmodified plant. Coproduct solids are sold at $0.20 per pound of contained protein, reflecting their value as animal feed analogous to Distillers Dried Grain and Solubles (DDGS). Acetic acid is also sold as a minor byproduct at $0.17 per pound. Sales, administrative and research (SAR) costs are included as 1% of revenue.

The sensitivity of the base case rate of return to financial assumptions is shown in Table 3. The Base Case return on investment of 23% falls by less than 5% for reasonable increases in feedstock cost, decreases in coproduct solids value, or loss of tax credits. Borrowing 50 to 70% of the initial capital at today's rates of interest will increase the owner's return on investment by at least 10%.

Table 4

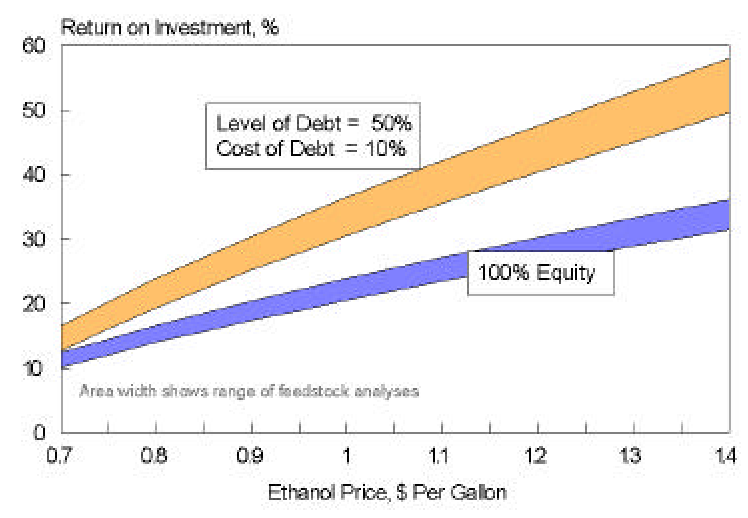
Cash Flow Sensitivities

From Portales Base Case

Feedstock Quality	Pct. Equity, Cost of Debt, Pct.	SPTC	NPV_{12}, \$MM
Base Case(Low)	100, 0	Yes	18
	100, 0	No	12
	50, 10	Yes	21
	50, 10	No	14
High	100, 0	No	17
	50, 10	Yes	29
	50, 10	No	20

Cash flow for the converted facility is expected to be significant, with attractive Net Present Values at a 12% discount rate. A 12% discount rate was felt to be appropriate for the ethanol production industry. Table 4 shows that for the Base Case feedstock analysis, the NPV_{12} is about \$18 million if the small producer tax credit is available, and around \$14 million if it is not. For feedstock richer in cellulose, the NPV_{12} is about \$7 million higher than for the Base Case analysis feedstock.

Figure 3
Impact of Ethanol Price on Project Profitability



Further analysis of the sensitivity of the financial results to variations in the financial parameters is given by Figures 3 though 6. Figures 3 and 4 show the impacts of ethanol value, feedstock quality, debt financing and the SPTC on the project DCF-ROI. Two bands are shown on each plot, one for no borrowing (100% equity financing) and one using 50% debt at 10% interest. The bottom of the band shows results for the Base Case (low) quality feedstock, and the upper limit of the band shows results for high quality feedstock (higher cellulose content). The x-axis shows ethanol values from \$0.70/gallon to \$1.40/gallon in year

2000; current ethanol value at Portales is $1.10/gallon. Figure 3 shows results including the small producer tax credit, and Figure 4 presents the results without that credit. The conclusion suggested by these figures is that the proposed modifications are financially attractive over all known predictions for the value of ethanol in the marketplace.

Figure 4
Impact of Ethanol Price on Project Profitability
No Small Producer Tax Credit

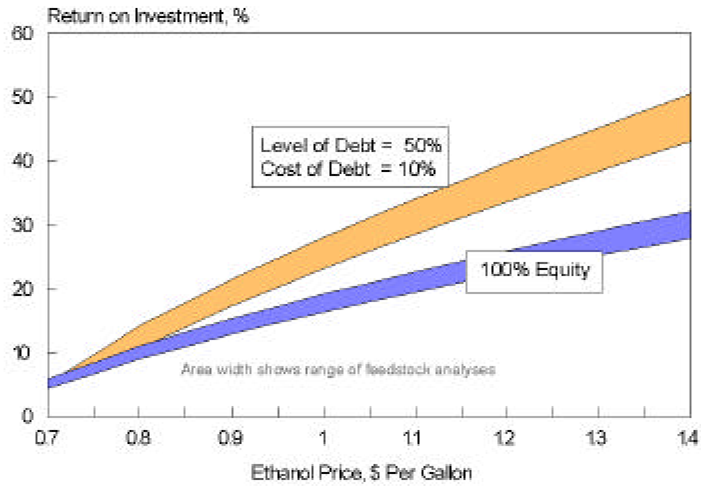


Figure 5 on the following page illustrates the impact that changes in feedstock price have on the DCF-ROI of the converted facility. Although some payment to the suppliers of the feedstock might be possible, that payment could only be a small one. As discussed under Work Element 1 results above, the feedstock owners are willing to enter into long-term contracts to supply cotton gin waste for zero cost. The material is a disposal problem for the gin operators at the present time. There is at least four times as much feedstock produced annually in the Portales area than is needed, without consideration of the existing large piles of CGT at each of the cotton processing plants. It seems likely that feedstock supply will be secured at low cost.

Figure 5
Impact of Feedstock Price on Project Profitability
Effect of Small Producer Tax Credit, 100% Equity Basis

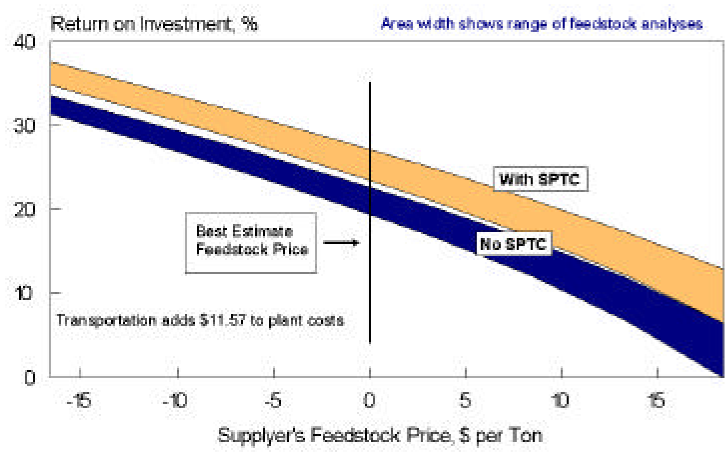
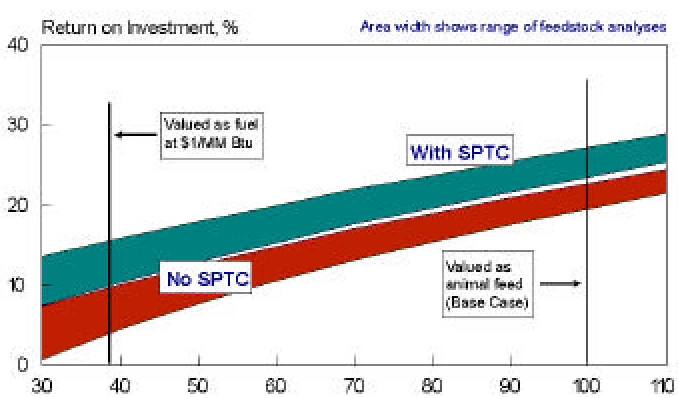


Figure 6 shows the impact of solid coproduct value on the DCF-ROI; the values shown are between the solids value as a boiler fuel, and the value as animal feed. The value as boiler fuel is assumed to be equal to that of low-BTU coal, $1 per million Btus. This valuation does not take credit for the valuable low sulfur content of the coproduct solids, nor take the credit for the very low boiler

Figure 6
Impact of Solids Value on Project Profitability
Effect of Small Producer Tax Credit, 100% Equity



fouling qualities of the coproduct solid when used as a fuel. Most biomass-based solid fuels suffer from high levels of fouling compounds, but the ethanol process removes most of these compounds from the solid coproduct. While the solid coproduct may not always be salable for the full protein value assumed in the Base Case, Figure 6 shows that lower sales prices will reduce the DCF-ROI, but not eliminate it. With the SPTC, the ROI gets no lower than about 9%, even if the solids are sold for fuel.

The effect of acetic acid value was also evaluated. Even at an unlikely acid value of zero, the Base Case DCF-ROI only falls 5%. Acetic acid is truly a minor byproduct.

Conclusions

This project has successfully identified a biomass feedstock in the Portales, NM area that could be used to manufacture ethanol at a cost significantly below current costs using milo as a feedstock. CGT is only modestly rich in carbohydrates, but is available in large quantities for the cost of hauling it to the ethanol plant.

SWAN Biomass and Weatherly Engineering developed a Base Case design for the modifications needed by High Plains Portales facility. The modifications would cost about $30 million in initial capital, with most of the expense related to addition of the SWAN pretreatment reactor and three large SSF tanks. Other changes include additions to the solids handling equipment, the distillation train, the solids separation equipment and some of the utilities. This capital cost is viewed as conservative because it considers all new equipment (High Plains has a history of buying used equipment, and suitable used equipment is likely available), the new anaerobic digestion proposed for installation prior to sending wastewater to municipal treating facilities may not be necessary, and there is a large contingency included in the total cost.

The economic outlook for the modified plant is excellent. The Base Case rate of return is 23.5%, and the net present value at a 12% discount rate would be $18 million. Sensitivity analysis shows that increases in cellulase enzyme or feedstock costs would significantly cut into the profits, but the modifications would still be justified financially. The Base Case assumes that the unreacted solids can be sold as an animal feed component, but even if the solid product is sold as a solid fuel, the project is still attractive. The rate of return on invested capital would increase significantly if part of the capital can be borrowed for construction at today's interest rates.

The economics of converting other types of biomass feedstocks available in the Portales area to ethanol do not appear to be attractive because of the expected cost of the feedstocks.

All of the partners in this project believe that even if High Plains sells the Portales facility, the new owners would be interested in making the plant more profitable, and the best way to do so appears to be to avoid the high cost of starch-rich feedstocks.

Recommendations

Modification of the Portales facility to utilize cotton gin trash feedstock appears to offer attractive financial returns under almost all reasonable circumstances. The following actions are needed before High Plains (or any facility owner) can be expected to proceed with project implementation.

The major need prior to engineering design of the modifications is for operating data using the SWAN process technology and cotton gin trash feedstock.

A second important study would be to determine possible variations in the composition of cotton gin trash. Different varieties of cotton, gin location, time of year, and freshness of the gin waste are all important variables that could affect the feedstock composition, and therefore ethanol yield.

Once hard data on the behavior of the feedstock in the proposed process are in hand, engineering design can focus on more precise estimates of capital costs.

The market for solid coproduct must also be confirmed. Feedlot tests may be necessary to establish a real value for the material.

Table 2
EXISTING EQUIPMENT

Item No.	Description	Status
B101	North Boiler	Existing
B102	South Boiler	Existing
C101 A,B,C,D	Grain Storage Fans	Existing
C102	Hammer Mill Fan	Existing
C104 A&B	Ethanol Blowers	Existing
C105	1st Stage Vapor Compressor	Existing
C106	2nd Stage Vapor Compressor	Existing
C107	Dust Collection Fan	Existing
C108	Reverse Air Fan	Existing
C109	Pellet Cooler Blower	Existing
C110	DDG Reverse Air Fan	Existing
C111	Grain Dust Transfer Fan	Existing
C112	Reverse Air Dust Fan	Existing
C113	Ducon Scrubber Fan	Existing
C114	Milled Grain Bin Fan	Existing
C115	Grain Receiving Scalper Fan	Existing
E102	Cook Hydroheater	Existing
E104	Beer still Economizer #1	Existing
E105	Prefermentation Cooler #1	Existing
E107 A&B	Propagation Coolers	Existing
E108 A,B,C,D,E	Fermenter Coolers	Existing
E109	Beer Still Preheater	Existing
E110	Absorber Preheater	Existing
E112	Regeneration Gas Condenser	Existing
E113	Evaporator and Beer Still Reflux Condenser	Existing
E114	Evaporator and Anhydrous Ethanol Condenser	Existing
E115	Vapor Compression Exchanger	Existing
E116 A&B	Feed/Condensate Exchanger	Existing
E117	Ethanol Product Cooler	Existing
E118	Beer Still Vent Condenser	Existing
E119	Anhydrous Ethanol Vent Condenser	Existing
E121	#2 Flash Condenser	Existing
E123	Regeneration Gas Superheater	Existing
E126	CO_2 Blower After Cooler	Existing
E127	CO_2 Scrubber Water Chiller	Existing
E129	E115 Vent Condenser	Existing
E210	140 Proof Heat Exchanger	Existing

Table 2
EXISTING EQUIPMENT

Item No.	Description	Status
E211	Cook Condensate Exchanger	Existing
F102	Centrifuge	Existing
F103	Ethanol Load Out Filter	Existing
H101	DDG Dryer	Existing
M101	Mix Vessel Agitator	Existing
M102	Primary Liquid Vessel Agitator	Existing
M103	Cook Vessel Agitator	Existing
M104	Secondary Liquid Vessel Agitator	Existing
M105 A&B	Propagator Agitators	Existing
M106	Secondary Liquid Vacuum System	Existing
M109 A,B,C,D,E	Fermenter Agitator	Existing
M110	Beer well Agitator	Existing
M111	Centrifuge Feed Tank Agitator	Existing
M112	Water Softener Package	Existing
M114 A&B	Boiler Chemical Treatment Package	Existing
M115	Cooling Water Treating Package	Existing
M116 A,B,C,D	Cooling Tower	Existing
M118 A&B	Ingersoll Rand Air Compressor	Existing
M118 D	Atlas Copco Air Compressor	Existing
M122	Process Water Agitator	Existing
M123	Lime Injection Package	Existing
M124	Alpha Amylase Injection Package	Existing
M125	Gluco Amylase Injection Package	Existing
M126	Sulfuric Acid Injection Package	Existing
M128	Ethanol Vapor Recovery System	Existing
M130 A&B	Instrument Air Dryer Package	Existing
M131	Chlorine Injection Package	Existing
M205	Ethanol Loadout Package	Existing
M206	Thin Stillage Agitator	Existing
M207	Inside Syrup Tank Agitator	Existing
M208	DDG Fan Package	Existing
MH101	Grain Unloading Conveyor	Existing
MH102 A&B	Grain Scalpers	Existing
MH103	Whole Grain Leg	Existing
MH104 A&B	Silo Conveyors	Existing
MH105	Hammer Mill Feed Elevator	Existing
MH106	Hammer Mill Rotary Feeder	Existing
MH107	Hammer Mill	Existing
Item No.	**Description**	**Status**

Table 2
EXISTING EQUIPMENT

MH111	Dryer Feed Blender	Existing
MH112	Dryer Feed Conveyor	Existing
MH114	Recycle Control Rotary Lock	Existing
MH115	Recycle Conveyor	Existing
MH116	Wet cake Exit Conveyor	Existing
MH117	DDG Paddle Drag Conveyor	Existing
MH118	White Silo Elevator	Existing
MH119	White Silo Unloading Elevator	Existing
MH120	Wet Cake Conveyor to Loadout	Existing
MH121	Wet Cake Loadout Conveyor	Existing
MH124	DDG Recycle Conveyor to MH115	Existing
MH126	Milled Grain Elevator	Existing
MH128	Grain Dust Collection System	Existing
MH129 A,B,C	Dryer Exit Conveyors	Existing
MH130	Feed Transfer Conveyor	Existing
MH131	Centrifuge Cake Conveyor	Existing
MH132	Dust Collection Rotary Feeder	Existing
MH134	Grain Dust Filter	Existing
MH135	Scalper Fines Hammer Mill	Existing
MH136	DDG Storage Conveyor	Existing
MH138	Wet cake Reclaim Blender	Existing
MH139	Wet cake Reclaim Conveyor	Existing
P101 A&B	Primary Liquid Pumps	Existing
P102 A&B	Secondary Liquid Pumps	Existing
P105 A&B	Cook Condensate Pumps	Existing
P108	Gluco Transfer Pumps	Existing
P110 A&B	Cook Vacuum Pumps	Existing
P113 A&B	Propagator Pumps	Existing
P114 A,B,C,D,E	Fermenter Pumps	Existing
P115 A&B	Beer well Pumps	Existing
P116 A&B	CO_2 Scrubber Pumps	Existing
P117 A&B	Hot Stillage Pumps	Existing
P118 A&B	Recovered Water Pumps	Existing
P119	Fusel Oil Extractor Pump	Existing
P120 A&B	E113 Feed Pumps	Existing
P121 A&B	Purge Recovery Pumps	Existing
P122 A&B	Regeneration Vacuum Pumps	Existing
P123 A&B	Beer Still Reflux Pumps	Existing

Table 2
EXISTING EQUIPMENT

Item No.	Description	Status
P126 A&B	Thin Stillage Pumps	Existing
P127 A&B	E113 Recirculation Pumps	Existing
P128 A&B	E114 Recirculation Pumps	Existing
P129	E115 Recirculation Pump	Existing
P130	E115 Recirculation Pump	Existing
P131	E115 Recirculation Pump	Existing
P132 A,B,C	Syrup Pumps	Existing
P133	Ethanol Surge Pump	Existing
P134	Denaturant Pump	Existing
P135	Ethanol Loading Pump	Existing
P136	Fusel Oil Pump	Existing
P137 A&B	Boiler Feedwater Pumps	Existing
P138 A&B	Cooling Water Pumps	Existing
P139 A&B	Sump Pumps	Existing
P139 C	Stillage Sump Pump	Existing
P139 D	Holding Pond Pump	Existing
P140	Wash Water Pump	Existing
P141	Waste Water Pump	Existing
P143 A&B	Process Water Pump	Existing
P144	Ethanol Rerun Pump	Existing
P145	Caustic Transfer Pump	Existing
P147	3% Caustic Pump	Existing
P148 A&B	Condensate Return Pumps	Existing
P149 A&B	Evaporator Syrup Pumps	Existing
P150	Evaporator Vacuum Pump	Existing
P151	E129 Condensate Pump	Existing
P152 A&B	Soft Water Pumps	Existing
P153	Denaturant Unloading Pump	Existing
P153 C	City Water Pump	Existing
P154	Fire Water Pump	Existing
P155 A&B	Centrate Pump	Existing
P156 A&B	Chilled Water Pump	Existing
P157	Fire Water Jockey Pump	Existing
P158	C105 Drain Pump	Existing
P159	C106 Drain Pump	Existing
P160 A&B	Cooling Water Treatment Pumps	Existing
P161	CO_2 Knock Out Pump	Existing
P162	Sulfamic Pump	Existing
Item No.	**Description**	**Status**

Table 2
EXISTING EQUIPMENT

P166	Weigh Scale Pump	Existing
P202	Bulk Gluco Pump	Existing
P203	Bulk Alpha Pump	Existing
P204	Loaf Tank Pump	Existing
P207	SAC Tank Pump	Existing
T101	Grain Receiving Building	Existing
T102 A&B	Grain Silo	Existing
T103	Hammer Mill Feed Bin	Existing
T104	Milled Grain Storage Bin	Existing
T105	White Silo	Existing
T107	Sulfamic Tank	Existing
T108	Gluco Amylase Tank	Existing
T109 A,B,C,D,E	Fermenters	Existing
T110	Beer Well	Existing
T111	Centrifuge Feed Tank	Existing
T112	Evaporator Feed Tank	Existing
T113 A,B,C,D	Syrup Tanks	Existing
T114 A&B	Ethanol Surge Tank	Existing
T115	Denaturant Tank	Existing
T116 A&B	Ethanol Storage Tanks	Existing
T117	Fusel Oil Storage Tank	Existing
T119	Wash Water Tank	Existing
T120	Waste Water Tank	Existing
T121	Process Sump	Existing
T122	Process Water Tank	Existing
T123	Ethanol Rerun Tank	Existing
T124	Caustic Storage Tank	Existing
T125	Caustic Wash Tank	Existing
T126	Softened Water Tank	Existing
T127	Fire Water Tank	Existing
T128	Scalper Fines Hopper	Existing
T130 A&B	Betz Chemical Tank	Existing
T131	Sulfuric Acid Tank	Existing
T132	Bulk Gluco Tank	Existing
T133	Bulk Alpha Tank	Existing
T134	Loaf Tank	Existing
T135	SAC Tank	Existing
V101	Cook Mix Vessel	Existing

Table 2
EXISTING EQUIPMENT

Item No.	Description	Status
V104	Secondary Liquid Vessel	Existing
V105 A&B	Propagators	Existing
V108	CO_2 Scrubber	Existing
V109	Beer Still	Existing
V110	Water Concentration Column	Existing
V112 A,B,C	Adsorber	Existing
V113	140 Proof Vessel	Existing
V114	E113 Vapor Drum	Existing
V115	E114 Vapor Drum	Existing
V116	E115 Vapor Drum	Existing
V117	Balance Vessel	Existing
V118	C105 Suction Separator	Existing
V119	C106 Suction Separator	Existing
V120	Hot Condensate Drum	Existing
V121	Deaerator	Existing
V123	Regeneration Vacuum Pump Separator	Existing
V124	Blowdown Drum	Existing
V125	Centrate Vessel	Existing
V126	CO_2 Knock Out Drum	Existing
V127	Beer Still Reflux Drum	Existing
V128	Anhydrous Ethanol Drum	Existing
V129	Evaporator Condensate Drum	Existing
V130	DDG Dryer Vapor Drum	Existing
V131	Evaporator Vacuum Pump K.O. Drum	Existing
V132	Air Receiver	Existing
V133	Anhydrous Ammonia Tank	Existing